VI. *A numerical Table of elective Attractions; with Remarks on the Sequences of double Decompositions. By* Thomas Young, *M. D. For. Sec. R. S.*

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ATTEMPTS have been made, by several chemists, to obtain a series of numbers, capable of representing the mutual attractive forces of the component parts of different salts; but these attempts have hitherto been confined within narrow limits, and have indeed been so hastily abandoned, that some very important consequences, which necessarily follow from the general principle of a numerical representation, appear to have been entirely overlooked. It is not impossible, that there may be some cases, in which the presence of a fourth substance, besides the two ingredients of the salt, and the medium in which they are dissolved, may influence the precise force of their mutual attraction, either by affecting the solubility of the salt, or by some other unknown means, so that the number, naturally appropriate to the combination, may no longer correspond to its affections; but there is reason to think that such cases are rare; and when they occur, they may easily be noticed as exceptions to the general rules. It appears therefore, that nearly all the phenomena of the mutual actions of a hundred different salts may be correctly represented by a hundred numbers, while, in the usual manner of relating every case as a different experiment, above two thousand separate articles would be required.

Having been engaged in the collection of a few of the principal facts relating to chemistry and pharmacy, I was induced to attempt the investigation of a series of these numbers; and I have succeeded, not without some difficulty, in obtaining such as appear to agree sufficiently well with all the cases of double decompositions which are fully established, the exceptions not exceeding twenty, out of about twelve hundred cases enumerated by FOURCROY. The same numbers agree in general with the order of simple elective attractions, as usually laid down by chemical authors; but it was of so much less importance to accommodate them to these, that I have not been very solicitous to avoid a few inconsistencies in this respect, especially as many of the bases of the calculation remain uncertain, and as the common tables of simple elective attractions are certainly imperfect, if they are considered as indicating the order of the independent attractive forces of the substances concerned. Although it cannot be expected that these numbers should be accurate measures of the forces which they represent, yet they may be supposed to be tolerable approximations to such measures, at least if any two of them are nearly in the true proportion, it is probable that the rest cannot deviate very far from it: thus, if the attractive force of the phosphoric acid for potash is about eight tenths of that of the sulfuric acid for barita, that of the phosphoric acid for barita must be about nine tenths as great; but they are calculated only to agree with a certain number of phenomena, and will probably require many alterations, as well as additions, when all other similar phenomena shall have been accurately investigated.

There is, however, a method of representing the facts, which

have served as the bases of the determination, independently of any hypothesis, and without being liable to the contingent necessity of any future alteration, in order to make room for the introduction of the affections of other substances; and this method enables us also to compare, upon general principles, a multitude of scattered phenomena, and to reject many which have been mentioned as probable, though doubtful, with the omission of a very few only which have been stated as ascertained. This arrangement simply depends on the supposition, that the attractive force, which tends to unite any two substances, may always be represented by a certain constant quantity.

From this principle it may be inferred, in the first place, that there must be a sequence in the simple elective attractions. For example, there must be an error in the common tables of elective attractions, in which magnesia stands above ammonia under the sulfuric acid, and below it under the phosphoric, and the phosphoric acid stands above the sulfuric under magnesia, and below it under ammonia, since such an arrangement implies, that the order of the attractive forces is this; phosphate of magnesia, sulfate of magnesia, sulfate of ammonia, phosphate of ammonia, and again phosphate of magnesia; which forms a circle, and not a sequence. We must therefore either place magnesia above ammonia under the phosphoric acid, or the phosphoric acid below the sulfuric under magnesia; or we must abandon the principle of a numerical representation in this particular case.

In the second place, there must be an agreement between the simple and double elective attractions. Thus, if the fluoric acid stands above the nitric under barita, and below it under

lime, the fluate of barita cannot decompose the nitrate of lime, since the previous attractions of these two salts are respectively greater, than the divellent attractions of the nitrate of barita and the fluate of lime. Probably, therefore, we ought to place the fluoric acid below the nitric under barita; and we may suppose, that when the fluoric acid has appeared to form a precipitate with the nitrate of barita, there has been some fallacy in the experiment.

The third proposition is somewhat less obvious, but perhaps of greater utility: there must be a continued sequence in the order of double elective attractions; that is, between any two acids, we may place the different bases in such an order, that any two salts, resulting from their union, shall always decompose each other, unless each acid be united to the base nearest to it: for example, sulfuric acid, barita, potass, soda, ammonia, strontia, magnesia, glycina, alumina, zirconia, lime, phosphoric acid. The sulfate of potass decomposes the phosphate of barita, because the difference of the attractions of barita for the sulfuric and phosphoric acids is greater than the difference of the similar attractions of potass; and in the same manner the difference of the attractions of potass is greater than that of the attractions of soda; consequently the difference of the attractions of barita must be much greater than that of the attractions of soda, and the sulfate of soda must decompose the phosphate of barita: and in the same manner it may be shown, that each base must preserve its relations of priority or posteriority to every other in the series. It is also obvious that, for similar reasons, the acids may be arranged in a continued sequence between the different bases; and when all the decompositions of a certain number of salts

have been investigated, we may form two corresponding tables, one of the sequences of the bases with the acids, and another of those of the acids with the different bases; and if either or both of the tables are imperfect, their deficiencies may often be supplied, and their errors corrected, by a repeated comparison with each other.

In forming tables of this kind from the cases collected by FOURCROY, I have been obliged to reject some facts, which were evidently contradictory to others, and these I have not thought it necessary to mention; a few, which are positively related, and which are only inconsistent with the principle of numerical representation, I have mentioned in notes; but many others, which have been stated as merely probable, I have omitted without any notice. In the table of simple elective attractions, I have retained the usual order of the different substances; inserting again in parentheses such of them as require to be transposed, in order to avoid inconsequences in the simple attractions: I have attached to each combination marked with an asterisc the number deduced from the double decompositions, as expressive of its attractive force; and where the number is inconsistent with the corrected order of the simple elective attractions, I have also inclosed it in a parenthesis. Such an apparent inconsistency may perhaps in some cases be unavoidable, as it is possible that the different proportions of the masses concerned, in the operations of simple and compound decomposition, may sometimes cause a real difference in the comparative magnitude of the attractive forces. Those numbers, to which no asterisc is affixed, are merely inserted by interpolation, and they can only be so far employed for determining the mutual actions of the salts to which they belong,

as the results which they indicate would follow from the comparison of any other numbers, intermediate to the nearest of those, which are more correctly determined. I have not been able to obtain a sufficient number of facts relating to the metallic salts, to enable me to comprehend many of them in the tables.

It has been usual to distinguish the attractions, which produce the double decompositions of salts, into necessary and superfluous attractions; but the distinction is neither very accurate, nor very important: they might be still further divided, accordingly as two, three, or the whole of the four ingredients concerned are capable of simply decomposing the salt in which they are not contained; and if two, accordingly as they are previously united or separate; such divisions would however merely tend to divert the attention from the natural operation of the joint forces concerned.

It appears to be not improbable, that the attractive force of any two substances might, in many cases, be expressed by the quotient of two numbers appropriate to the substances, or rather by the excess of that quotient above unity; thus the attractive force of many of the acids for the three principal alkalies might probably be correctly represented in this manner; and where the order of attractions is different, perhaps the addition of a second, or of a second and third quotient, derived from a different series of numbers, would afford an accurate determination of the relative force of attraction, which would always be the weaker, as the two substances concerned stood nearer to each other in these orders of numbers; so that, by affixing, to each simple substance, two, three, or at most

four numbers only, its attractive powers might be expressed in the shortest and most general manner.

I have thought it necessary to make some alterations in the orthography generally adopted by chemists, not from a want of deference to their individual authority, but because it appears to me that there are certain rules of etymology, which no modern author has a right to set aside. According to the orthography universally established throughout the language, without any material exceptions, our mode of writing Greek words is always borrowed from the Romans, whose alphabet we have adopted: thus the Greek vowel Υ, when alone, is always expressed in Latin and in English by Y, and the Greek diphthong ΟΥ by U, the Romans having no such diphthong as OU or OY. The French have sometimes deviated from this rule, and if it were excusable for any, it would be for them, since their *u* and *ou* are pronounced exactly as the Υ and ΟΥ of the Greeks probably were: but we have no such excuse. Thus the French have used the term *acoustique*, which some English authors have converted into "acoustics;" our anatomists, however, speak, much more correctly, of the "acustic" nerve. Instead of glucine, we ought certainly, for a similar reason, to write glycine; or glycina, if the names of the earths are to end in *a*. Barytes, as a single Greek word, means weight, and must be pronounced bárytes; but as the name of a stone, accented on the second syllable, it must be written barites; and the pure earth may properly be called barita. Yttria I have altered to itria, because no Latin word begins with a Y.

Table of the Sequences of the Bases with the different Acids.

In all mixtures of the aqueous solutions of two salts, each acid remains united to the base which stands nearest to it in this table.

SULFURIC ACID.

Barita	Barita	Barita	Barita	Barita	Barita	Potass	Barita	Barita	Lead
Strontia	Strontia	Potass	Potass	Potass	Potass	Soda	Strontia	Potass	Mercury
Lime	Lime	Soda	Soda	Soda	Soda	Barita	Lime	Soda	Iron
(Silver ?)	Potass	Ammonia	Strontia	Strontia	Strontia	Strontia	Potass	Ammonia	Potass
(Mercury ?)	Soda	Strontia	Ammonia	Ammonia (4)	Ammonia (5)	Ammonia (6)	Soda	Strontia	Soda
Potass	(Mercury ?)	Magnesia (3)	Magnesia	Magnesia (4)	Magnesia	Lime	Magnesia ?	Magnesia	Magnesia
Soda	(Iron ?)	Glycina	Glycina	Glycina	Lime	Magnesia	Ammonia	Glycina	
Zinc	Magnesia	Alumina	Alumina	Alumina	Glycina	Glycina	Glycina	Alumina	Lead
Iron	Ammonia (2)	Zirconia	Zirconia	Zirconia	Alumina	Alumina	Alumina	Zirconia	Zinc
Copper	Glycina	Lime	Lime	Lime	Zirconia	Zirconia	Zirconia	Lime ?	Copper
Magnesia	Alumina (2)								
Ammonia (1)	Zirconia								
Glycina	(Copper ?)								
Alumina									
Zirconia									
NITRIC	MURIATIC	PHOSPHORIC	FLUORIC	SULFUROUS	BORACIC	CARBONIC	(NITROUS)	(PHOSPHOROUS)	(ACETIC)

(1) Ammonia stands above magnesia when cold. (2) A triple salt is formed. (3) Perhaps magnesia ought to stand lower (4) A compound salt is formed, and when hot, magnesia stands above ammonia. (5) FOURCROY says, that sulfate of strontia is decomposed by borate of ammonia. (6) With heat, ammonia stands below lime and magnesia.

Nitric and Muriatic Acids.

Nitric Acid.	Nitric and Muriatic Acids.				
Barita	Potass	Barita	Potass	Barita (10)	Potass
Potass	Soda	Potass	Soda	Potass	Soda
Soda	Ammonia	Soda	Ammonia	Soda	Barita (10)
Strontia	Magnesia	Ammonia	Magnesia	Ammonia	Ammonia (7, 11)
Lime	Glycina	Magnesia	Glycina	Magnesia	Magnesia (7)
Magnesia (7)	Alumina	Glycina	Alumina	Glycina	Strontia
Ammonia (7)	Zirconia (8)	Alumina	Zirconia	Alumina	Lime
Glycina	Barita	Zirconia	Barita	Zirconia	Glycina
Alumina	Strontia	Strontia (9)	Strontia	Strontia	Alumina
Zirconia	Lime	Lime	Lime	Lime	Zirconia
MURIATIC	PHOSPHORIC	FLUORIC	SULFUROUS	BORACIC	CARBONIC

(7) A triple salt is formed. (8) FOURCROY says, that the muriate of zirconia decomposes the phosphates of barita and strontia. (9) According to FOURCROY's account, the fluate of strontia decomposes the muriates of ammonia, and of all the bases below it; but he says in another part of the same volume, that the fluate of strontia is an unknown salt. (10) According to FOURCROY's account of these combinations, barita should stand immediately below ammonia in both of these columns. (11) With heat, the carbonate of lime decomposes the muriate of ammonia.

Phosphoric Acid.

Barita	Lime	Barita	Potass	Barita
Lime	Barita	Lime	Soda	Lime
Potass	Potass	Potass	Barita	Potass
Soda	Soda	Soda	Lime (13)	Soda
Strontia	Strontia	Strontia	Strontia	Strontia
Magnesia	Magnesia	Ammonia (12)	Ammonia	Magnesia
Ammonia	Ammonia	Magnesia	Magnesia	Glycina?
Glycina	Glycina	Glycina	Glycina	Alumina
Alumina	Alumina	Alumina	Alumina	Zirconia
Zirconia	Zirconia	Zirconia	Zirconia	
FLUORIC	SULFUROUS	BORACIC	CARBONIC	(PHOSPHOROUS)

(12) According to FOURCROY, the phosphate of ammonia decomposes the borate of magnesia. (13) FOURCROY says, that the carbonate of lime decomposes the phosphates of potass and of soda.

Fluoric Acid.

Lime	Lime	Potass
Potass	Barita	Soda
Soda	Strontia	Lime
Magnesia	Potass	Barita
Ammonia	Soda	Strontia
Glycina	Ammonia	Ammonia (14)
Alumina	Magnesia	Magnesia
Zirconia	Glycina	Glycina
Strontia	Alumina	Alumina
Barita	Zirconia	Zirconia
SULFUROUS	BORACIC	CARBONIC

(14) According to FOURCROY, the carbonate of ammonia decomposes the fluates of barita and strontia.

Sulfurous Acid.				Boracic Acid.
Barita	Potass	Lime	Zirconia	Potass
Strontia	Soda	Strontia	Alumina	Soda
Potass	Barita (15)	Barita	Glycina	Lime
Soda	Strontia	Zirconia	Ammonia	Barita
Ammonia	Ammonia	Alumina	Magnesia	Strontia
Magnesia	Lime	Glycina	Strontia	Magnesia
Lime	Magnesia	Magnesia	Soda	Ammonia
Glycina	Glycina	Ammonia	Potass	Glycina
Alumina	Alumina	Soda	Barita	Alumina
Zirconia	Zirconia	Potass	Lime	Zirconia
Boracic	Carbonic	(Nitrous)	(Phosphorous?)	Carbonic

(15) Fourcroy says, that the sulfite of barita decomposes the carbonate of ammonia.

Table of the Sequences of the Acids with different Bases.

	Barita.			Strontia.					Lime.			
Sulfuric	S	C	S	S	C	S	P	S	C	P	P	P
Nitric	N	S	P	N	SS	P	S	P	P	F	F	F
Muriatic	M	P	SS	M	F	SS	SS	SS	F	B	B	SS
Phosphoric	SS	SS	N	SS	P	F	F	F	B	SS	C	S
Sulfurous	P	N	M	C	B	B	B	B	SS	S	SS	B
Fluoric	C	M	F	B	S	C	C	N	S	C	S	N
Boracic	B	F	B	F	M	N	N	M	M	N	N	M
Carbonic	F	B	C	P	N	M	M	C	N	M	M	C
Strontia	LM	PT	MG	LM	PT	MG	AM	GL	PT	MG	AM	GL
		SD	AM		SD			AL	SD			AL
			GL					ZR				ZR
			AL									
			ZR									

Potass
Soda
Magn.=Amm.
Glycina
Alumina
Zirconia
Each with every subsequent base in this order

	Magnesia.
S	B
N	C
M	P
P	F
F	SS
SS	S
B	N
C	M
	AM

The comparative use of this table may be understood from an example: if we suppose that the nitrate of barita decomposes the borate of ammonia, we must place the boracic acid above the nitric, between barita and ammonia in this table, and consequently barita below ammonia, between the fluoric and boracic in the former: hence the boracic and fluoric acids must also be transposed between barita and strontia, and between barita and potass; or if we place the fluoric still higher than the boracic in the first instance, we must place barita below ammonia between the nitric and fluoric acids, where indeed it is not impossible that it ought to stand.

Numerical Table of elective Attractions.

BARITA.		STRONTIA.		POTASS.		SODA.	LIME.	
Sulfuric acid	1000*	Sulfuric acid	903*	Sulfuric acid			Oxalic acid	960
Oxalic	950	Phosphoric	827*		894*	885*	Sulfuric	868*
Succinic	930	Oxalic	825	Nitric	812*	804*	Tartaric	867
Fluoric		Tartaric	757	Muriatic	804*	797*	Succinic	866
Phosphoric	906*	*Fluoric*		Phosphoric			Phosphoric	865*
Mucic	900	Nitric	754*		801*	795*	Mucic	860
Nitric	849*	Muriatic	748*	Suberic?	745	740	Nitric	741*
Muriatic	840*	(Succinic)	740	Fluoric	671*	666*	Muriatic	736*
Suberic	800	(Fluoric)	703*	Oxalic	650	645	Suberic	735
Citric		*Succinic*		Tartaric	616	611	Fluoric	734*
Tartaric	760	Citric?	618	Arsenic	614	609	Arsenic	$733\frac{3}{4}$
Arsenic	$733\frac{1}{2}$	Lactic	603	Succinic	612	607	*Lactic*	732
(Citric)	730	*Sulfurous*	527*	Citric	610	605	Citric	731
Lactic	729	*Acetic*		Lactic	609	604	Malic	700
(Fluoric)	706*	*Arsenic*	$(733\frac{1}{4})$	Benzoic	608	603	Benzoic	590
Benzoic	597	Boracic	513*	Sulfurous	488*	484*	*Acetic*	
Acetic	594	(Acetic)	480	Acetic	486	482	Boracic	537*
Boracic	(515)*	Nitrous?	430	Mucic	484	480	Sulfurous	516*
Sulfurous	592*	Carbonic	419*	Boracic	482*	479*	(Acetic)	470
Nitrous	450			Nitrous	440	437	Nitrous	425
Carbonic	420*			Carbonic	306*	304*	*Carbonic*	423*
Prussic	400			Prussic	300	298	Prussic	290

MAGNESIA.		AMMONIA.		GLYCINA?		ALUMINA.	ZIRCONIA?
Oxalic acid	820	Sulfuric acid	808*	Sulfuric acid	718*	709*	700*
Phosphoric		Nitric	731*	Nitric	642*	634*	626*
Sulfuric	810*	Muriatic	729*	Muriatic	639*	632*	625*
(Phosphoric)	736*	Phosphoric	728*	Oxalic	600	594	588
Fluoric		Suberic?	720	Arsenic	580	575	570
Arsenic	733	Fluoric	613*	Suberic?	535	530	525
Mucic	$732\frac{1}{2}$	Oxalic	611	Fluoric	534*	529*	524*
Succinic	$732\frac{1}{4}$	Tartaric	609	Tartaric	520	515	510
Nitric	732*	Arsenic	607	Succinic	510	505	500
Muriatic	728*	Succinic	605	Mucic	425	420	415
Suberic?	700	Citric	603	Citric	415	410	405
(Fluoric)	620*	Lactic	601	*Phosphoric*	(648)*	(642)*	(636)*
Tartaric	618	Benzoic	599	Lactic	410	405	400
Citric	615	Sulfurous	433*	Benzoic	400	395	390
Malic?	600?	Acetic	432	Acetic	395	391	387
Lactic	575	Mucic	431	Boracic	388*	385*	382*
Benzoic	560	Boracic	430*	Sulfurous	355*	351*	347*
Acetic		Nitrous	400	Nitrous	340	336	332
Boracic	459*	Carbonic	339*	Carbonic	325*	323*	321*
Sulfurous	439*	Prussic	270	Prussic	260	258	256
(Acetic)	430						
Nitrous	410						
Carbonic	366*						
Prussic	280						

Acids.

Sulfuric.	
Barita	1000*
Strontia	903*
Potass	894*
Soda	885*
Lime	868*
Magnesia	810*
Ammonia	808*
Glycina	718*
Itria	712
Alumina	709*
Zirconia	700*

Nitric.	
Barita	849*
Potass	812*
Soda	804*
Strontia	754*
Lime	741*
Magnesia	732*
Ammonia	731*
Glycina	642*
Alumina	634*
Zirconia	626*

Muriatic.	
Barita	840*
Potass	804*
Soda	797*
Strontia	748*
Lime	736*
Ammonia	729*
Magnesia	728*
Glycina	639*
Alumina	632*
Zirconia	625*

Phosphoric.	
Barita	906*
Strontia	827*
Lime	(865)*
Potass	801*
Soda	795*
Ammonia	(728)*
Magnesia	736*
Glycina	648*
Alumina	642*
Zirconia	636*

Fluoric.	
Lime	734*
Barita	706*
Strontia	703*
Magnesia	(620)*
Potass	671*
Soda	666*
Ammonia	613*
Glycina	534*
Alumina	529*
Zirconia	524*

	Oxalic.	Tartaric.
Lime	960	867
Barita	950	760
Strontia	825	757
Magnesia	820	618
Potass	650	616
Soda	645	611
Ammonia	611	609
Glycina ?	600	520
Alumina	594	515
Zirconia ?	588	510

Arsenic.	
Lime	$733\frac{3}{4}$
Barita	$733\frac{1}{2}$
Strontia	$733\frac{1}{4}$
Magnesia	733
Potass	614
Soda	609
Ammonia	607
Glycina	580
Alumina	575
Zirconia	570

Tungstic.
Lime
Barita
Strontia
Magnesia
Potass
Soda
Ammonia
Glycina
Alumina
Zirconia

Succinic.	
Barita	930
Lime	866
Strontia ?	740
(Magnesia)	$732\frac{1}{4}$
Potass	612
Soda	607
Ammonia	605
Magnesia	
Glycina ?	510
Alumina	505
Zirconia ?	500

Suberic.	
Barita	800
Potass	745
Soda	740
Lime	735
Ammonia	720
Magnesia	700
Glycina ?	535 ?
Alumina	530
Zirconia ?	525 ?

Camphoric.
Lime
Potass
Soda
Barita
Ammonia
Glycina ?
Alumina
Zirconia ?
Magnesia

Citric.	
Lime	731
Barita	730
Strontia	618
Magnesia	615
Potass	610
Soda	605
Ammonia	603
Glycina ?	415 ?
Alumina	410
Zirconia	405

Lactic.	
Barita	729
Potass	609
Soda	604
Strontia	603
Lime	(732)
Ammonia	601
Magnesia	575
Metallic oxids	
Glycina	410
Alumina	405
Zirconia	400

Benzoic.	
White oxid of arsenic	
Potass	608
Soda	603
Ammonia	599
Barita	597
Lime	590
Magnesia	560
Glycina ?	400 ?
Alumina	395
Zirconia ?	390 ?

Sulfurous.	
Barita	592 *
Lime	516 *
Potass	488 *
Soda	484 *
Strontia	(527)*
Magnesia	439 *
Ammonia	433 *
Glycina	355 *
Alumina	351 *
Zirconia	347 *

Acetic.	
Barita	594
Potass	486
Soda	482
Strontia	480
Lime	470
Ammonia	432
Magnesia	430
Metallic oxids	
Glycina	395
Alumina	391
Zirconia	387

MUCIC?	
Barita	900
Lime	860
Potass	484
Soda	480
Ammonia	431
Glycina	425
Alumina	420
Zirconia	415

BORACIC.	
Lime	537 *
Barita	515 *
Strontia	513 *
Magnesia	(459)*
Potass	482 *
Soda	479 *
Ammonia	430 *
Glycina	388 *
Alumina	385 *
Zirconia	382 *

NITROUS?	
Barita	450
Potass	440
Soda	437
Strontia	430
Lime	425
Magnesia	410
Ammonia	400
Glycina	340
Alumina	336
Zirconia	332

PHOSPHOROUS.
Lime
Barita
Strontia
Potass
Soda
Magnesia?
Ammonia
Glycina
Alumina
Zirconia

CARBONIC.	
Barita	420 *
Strontia	419 *
Lime	(423)*
Potass?	306 *
Soda	304 *
Magnesia	(366)*
Ammonia	339 *
Glycina	325 *
Alumina	323 *
Zirconia	321 *

PRUSSIC.	
Barita	400
Strontia	
Potass	300
Soda	298
Lime	290
Magnesia	280
Ammonia	270
Glycina?	260
Alumina?	258
Zirconia?	256